The Mesocortical Dopamine System Does Not Encode Reward Prediction Errors

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Background

One of the most influential theories in neuroscience states that dopamine (DA) projections to the forebrain convey Reward Prediction Errors (RPEs) in the service of reinforcement learning. This theory has been validated through countless Pavlovian conditioning experiments involving the mesolimbic and to a lesser extent, the nigrostriatal DA pathways. While it is often assumed that the theory also holds for the mesocortical DA system, Seamans & Yang (2004) cited a variety of reasons why this is unlikely. However, it has not been possible to broach the issue experimentally because microdialysis was the only technique available to accurately measure cortical DA levels and it is too slow to track transient DA changes on Pavlovian conditioning tasks. Newly developed, fast and highly-sensitive fluorescent DA sensors have overcome these limitations thereby allowing us to return to the question of whether the mesocortical DA system carries RPEs.

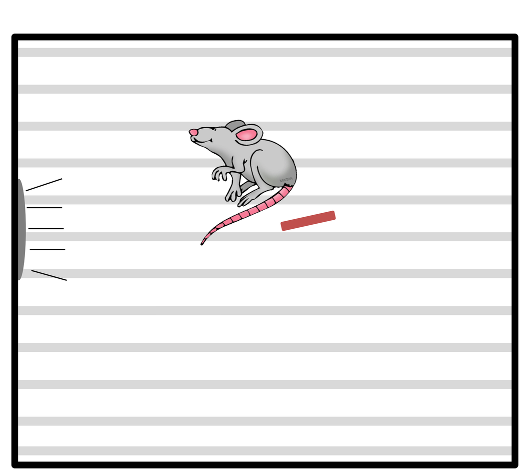
Objective: To investigate how the mesocortical DA system responds to the emotional sates evoked during the 3-valence task

Methods

Fiber Photometry

dLight2.1 or GRABDA3h Injected unilaterally into the medial prefrontal cortex (mPFC)

3-Valence Task Creates 3 unique 'emotional contexts'



Version 1: Frequency of the tone indicates the valence of the outcome

Shock Context:
- 5s tone 1 – 1.5s mild footshock

Food Context:
- 5s tone 2 – 3 food pellets

Neutral Context:
- 5s tone 3 – no outcome

Version 2: Duration of the tone indicates the value of the outcome

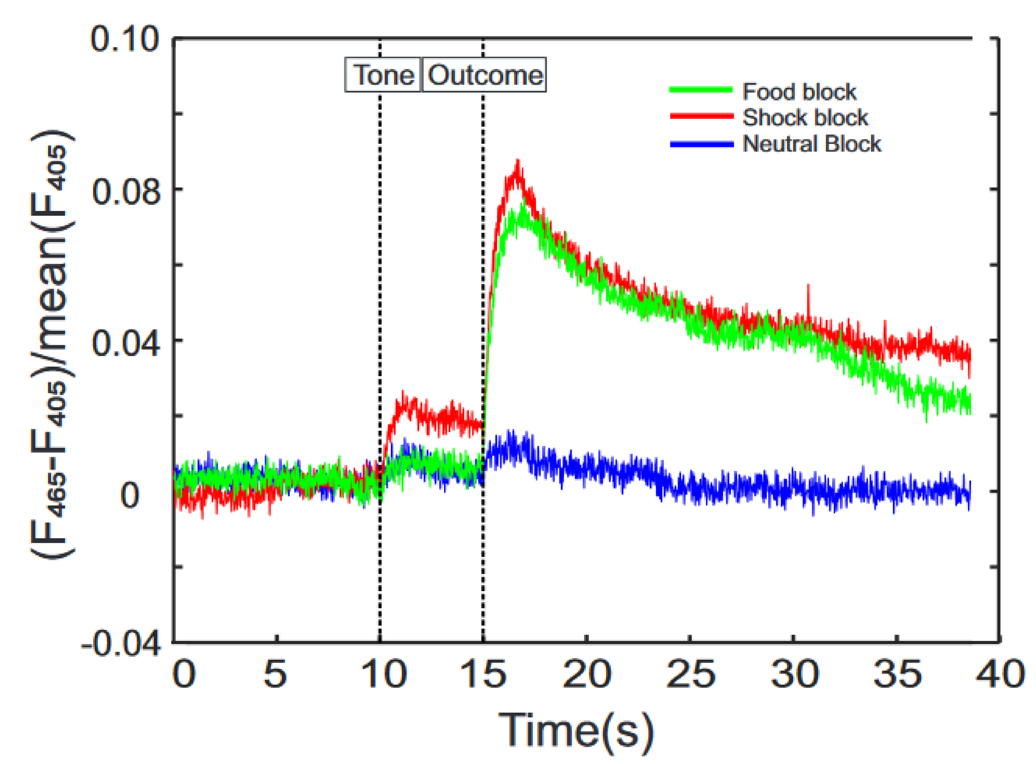
Shock Context:
- 5s tone 1 – 1.5s mild footshock
- 3s tone 1 – 0.5s mild footshock

Food Context:
- 5s tone 2 – 3 food pellets
- 3s tone 2 – 1 food pellet

Neutral Context:
- 5s tone 3 – no outcome
- 3s tone 3 – no outcome

Blocks of 15 tone + outcome pairings

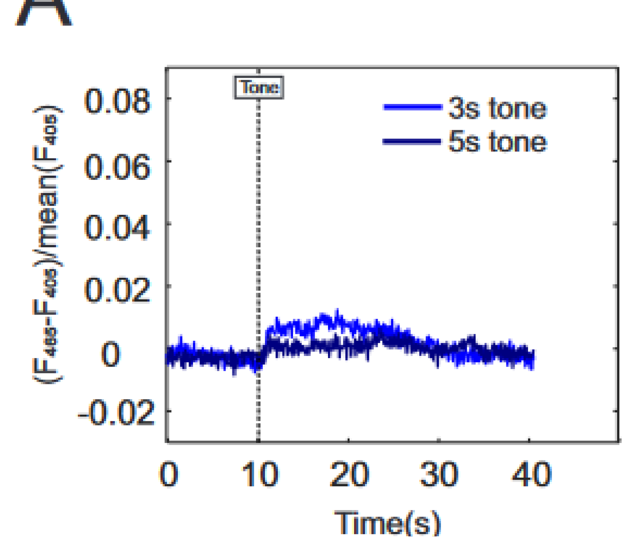
3-Valence Task Version 1



DA levels in the mPFC did not appear to encode events according to their emotional valence, as we observed an increase in DA efflux in response to both the rewarding (food pellet) and aversive outcomes (footshock).

3-Valence Task Version 2

A



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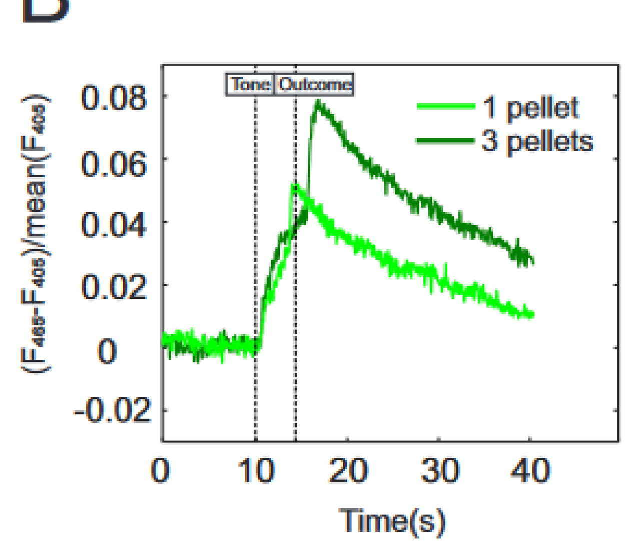

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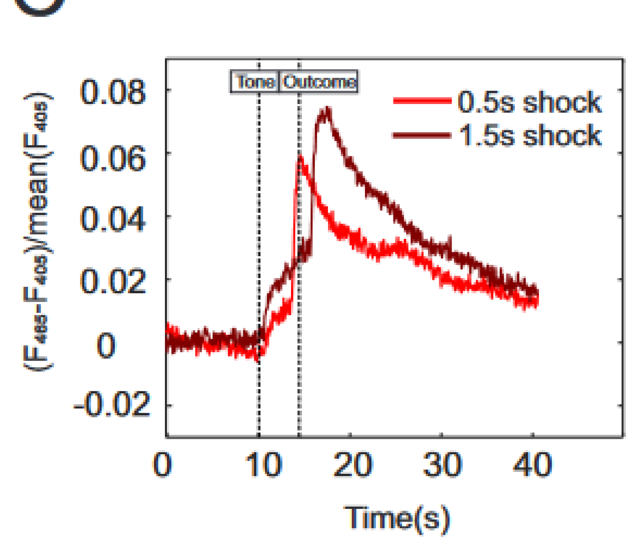
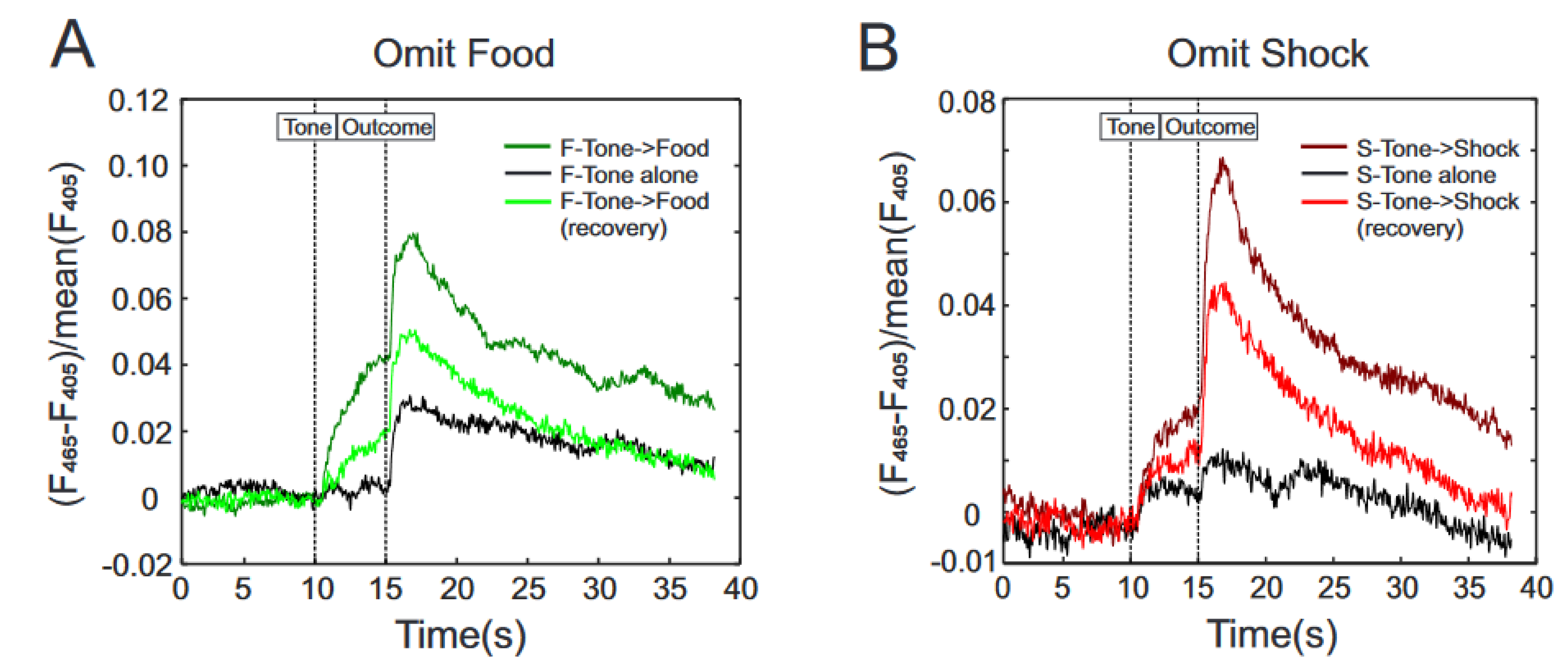


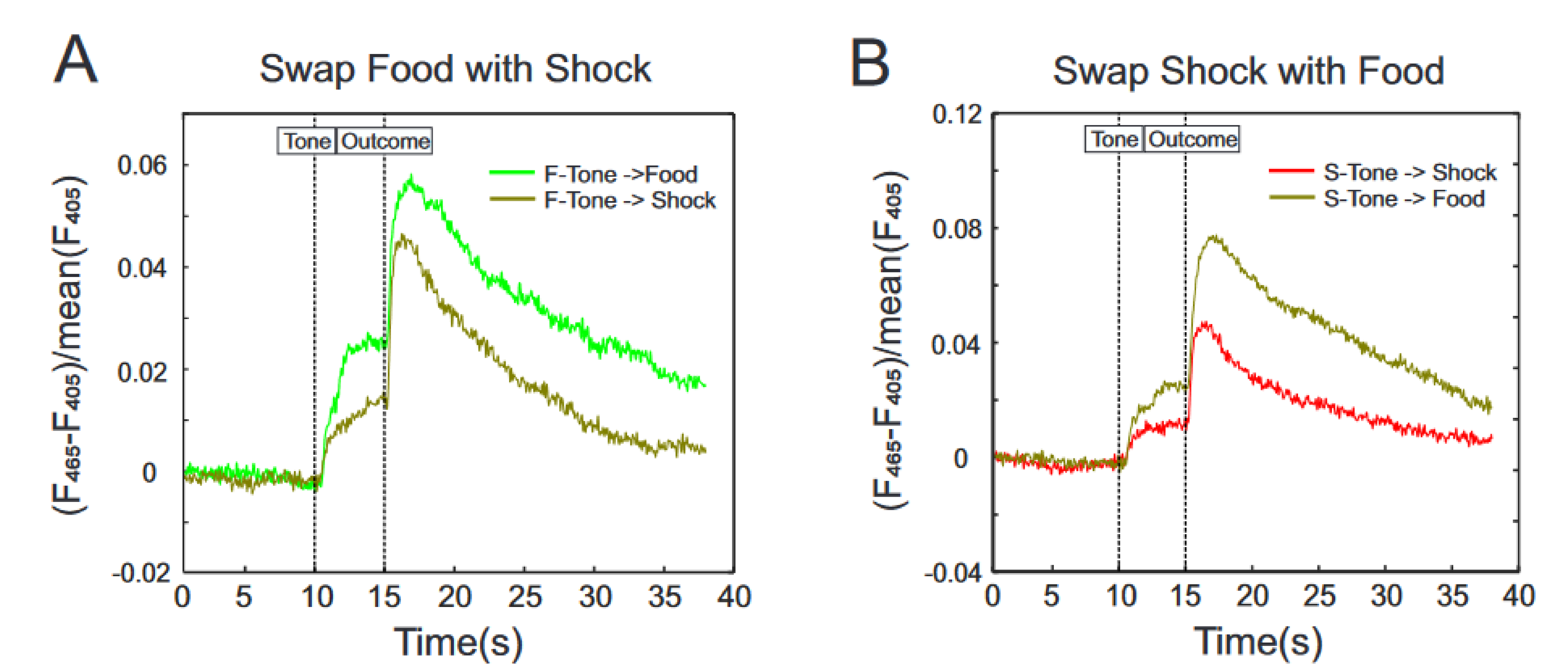
While DA responses varied with changes in outcome magnitude (ie more/less food pellets or shorter/longer shocks), the correlations were not linear and the effect was greater on food trials. 'Dips' in DA, consistent with negative RPEs, were never observed.

Omitting Outcomes



Omitting outcomes attenuated the outcome-locked increase in DA equally on food and shock trials.

Swapping Outcomes



Swapping the food with a shock on food trials should have created very strong negative RPEs, but this only slightly accentuated the outcome-locked increases in DA. Swapping the shocks with food on shock trials had the opposite effect

Conclusions

- These results suggest that mPFC DA does not track emotional valence but rather **autonomic salience**. In other words, any event expected to cause greater autonomic arousal will cause a greater increase in DA.
- The mesocortical DA system **does not appear to encode RPEs**, a conclusion which is consistent with the lack of effect of MFC DA manipulations on reinforcement learning tasks (Ellwood et al, 2017).

References

1. Seamans, J.K., & Yang, C.R. (2004). Prog Neurobiol. 74(1):1-58.
2. Ellwood, I.T., Patel, T., et al. (2017). J Neurosci. 37(35):8315-8329.

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